First results of Neptune observations with Herschel

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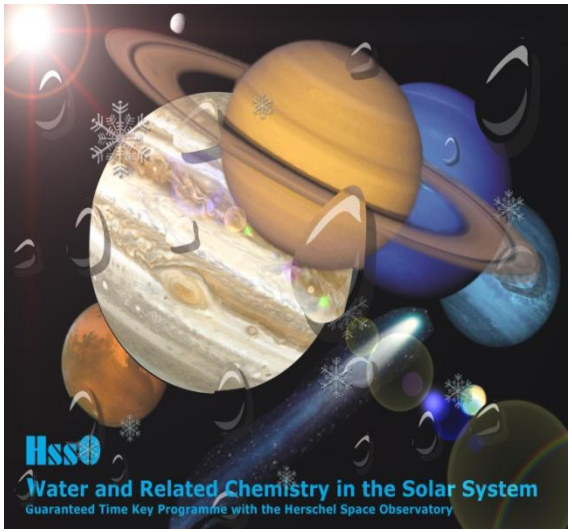
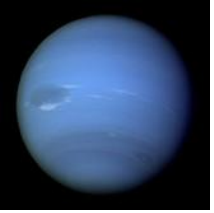




Scientific Context

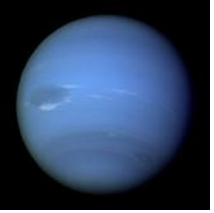
- Neptune's atmosphere is composed mainly of H_2 and He, and has a large CH_4 abundance in its troposphere. It also contains some other minor compounds : CO,H_2O,hydrocarbons, CO_2 and HCN

- Some important open questions:

-What is the D/H ratio ? implications on the composition of the icy grains that formed Neptune ?

-What is the CH_4 abundance in the stratosphere ? Implications for meteorological and vertical transport ?

-What are the CO and H_2O profiles in the stratosphere ? What is the flux of external oxygen ? Implication for the nature of oxygen sources (micrometeorites, comets, rings).



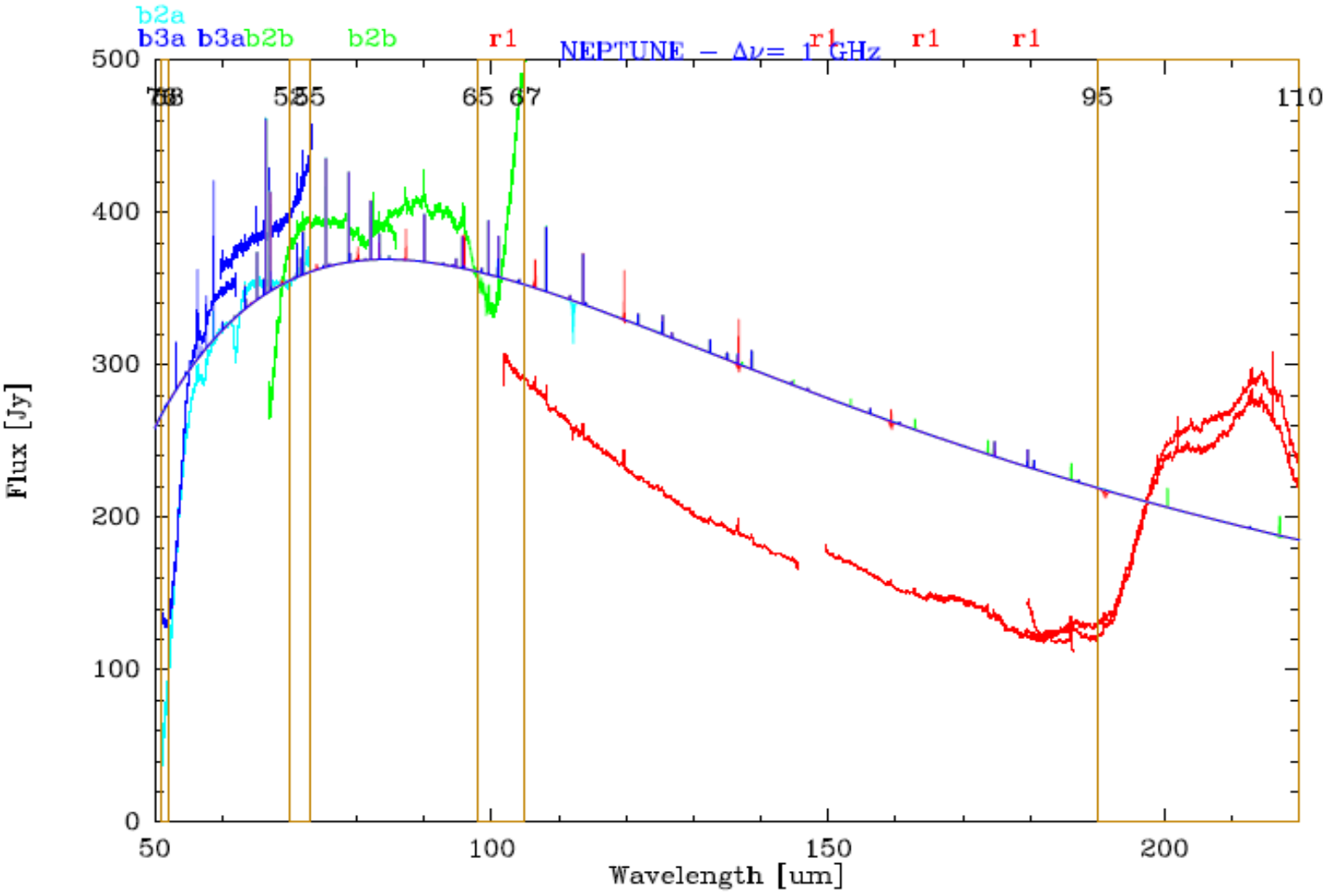
Herschel Observations

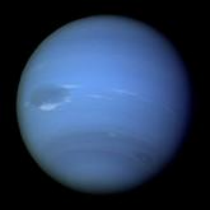
- Herschel Observations : PACS and SPIRE full range spectra of Neptune - on Oct. 30/31 2009 - altogether covering the 55-670 micron range.

- Neptune's angular diameter was of about 2.3", so unresolved with the Herschel PSFs.

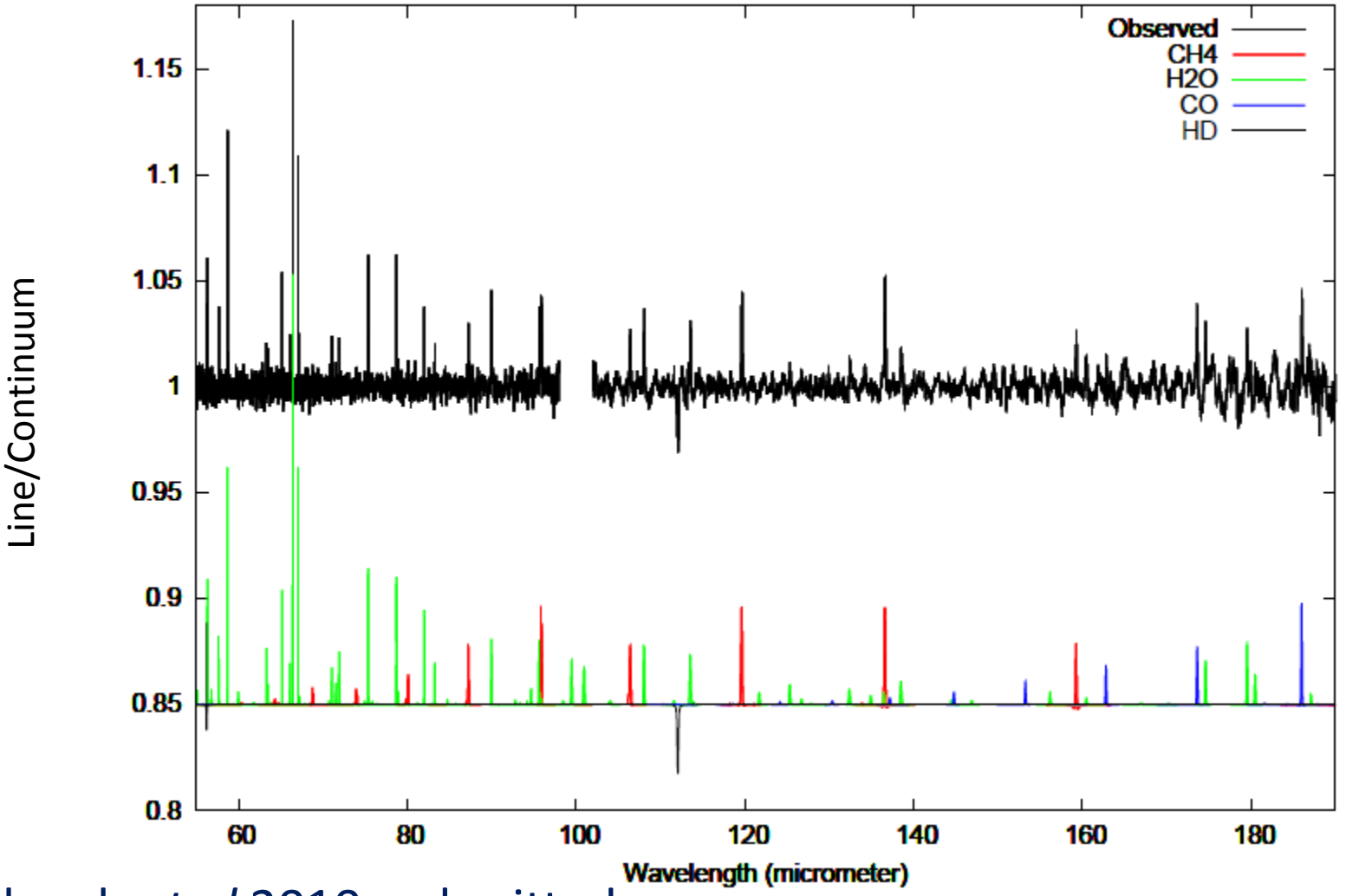
- Expected detectable lines : HD (56,112 µm),
- CH_4(87,95 119,156, … µm) , CO(162, 186, … µm) and
- H_2O(66,75,82, 108, 125, .. µm)

PACS SPECTRUM

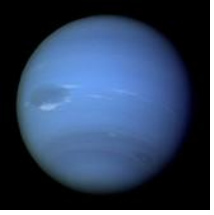




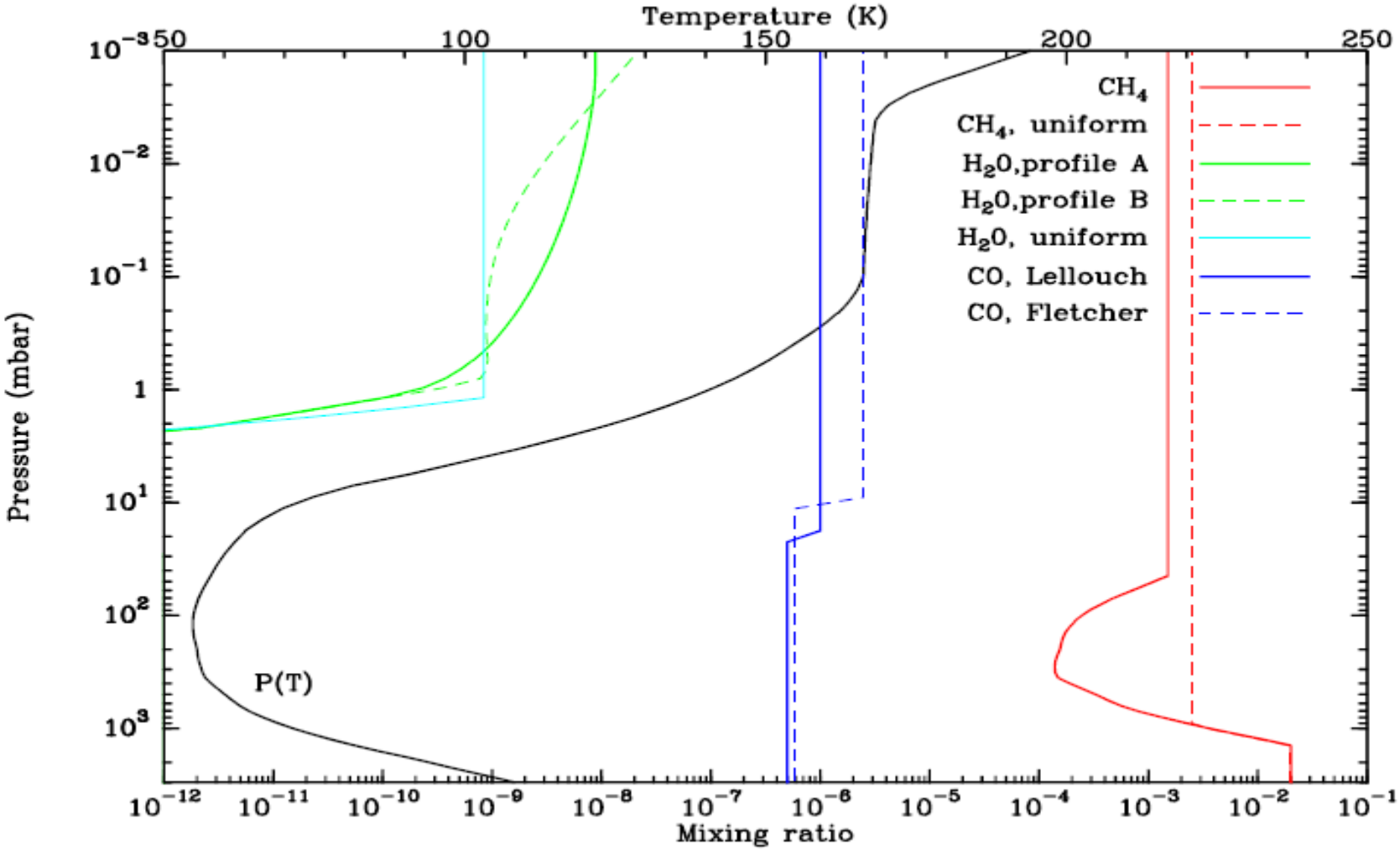
PACS Spectrum (Line/Continuum)

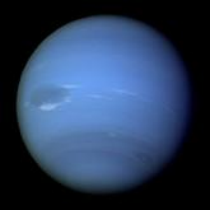


Lellouch *et al* 2010, submitted

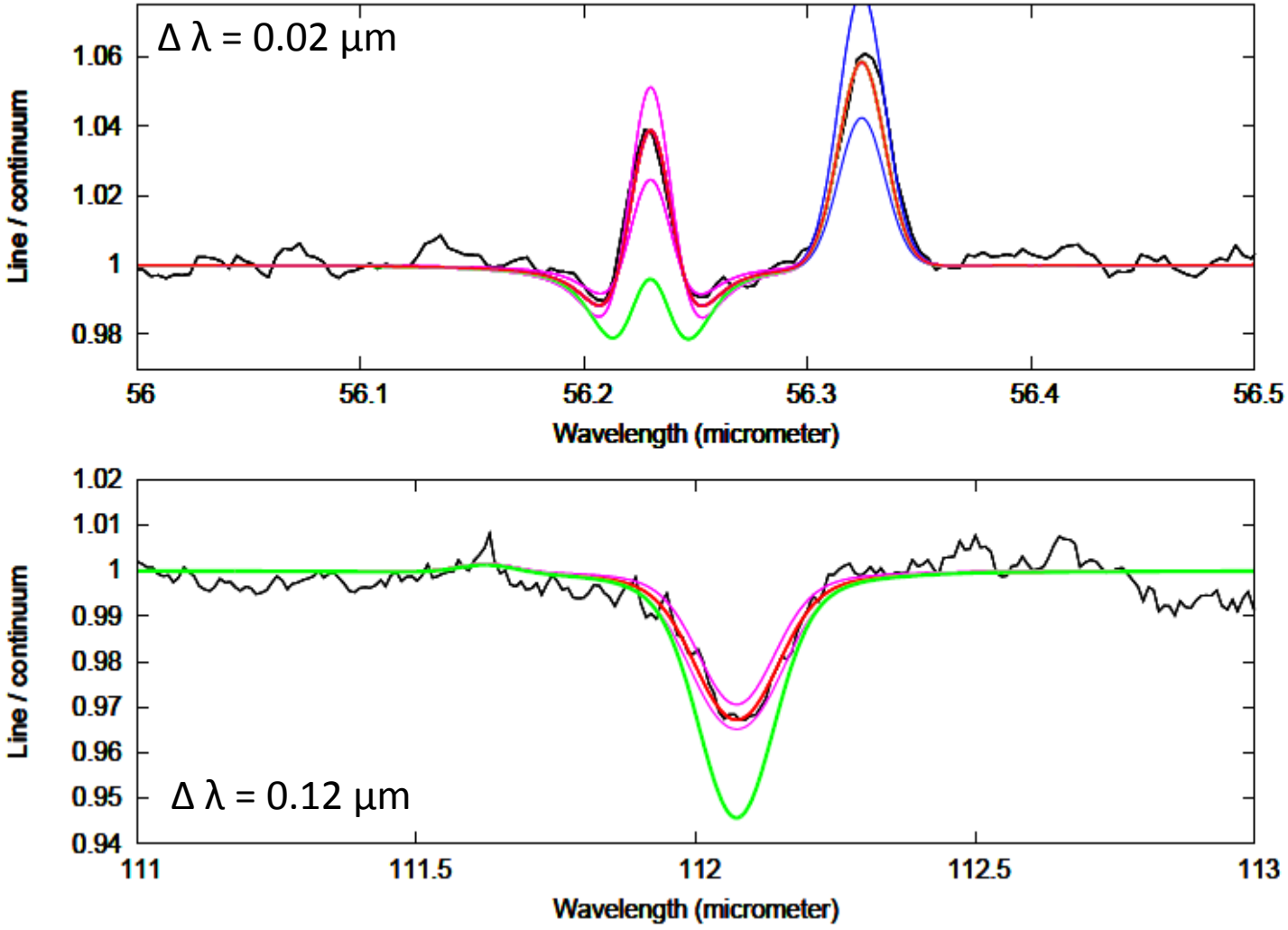


P(T) and Molecular profiles





HD - PACS

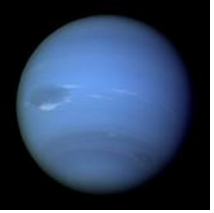


HD (6-9-12 x 10^{-5})
+ best P(T)

HD (910 $^{-5}$)
+ Colder P(T)

H_2O (profile A)

Observations



HD - Results

Thermal profile :

P(T) : best profile : 0.9x AKARI+0.1 Voyager (i.e. 3K warmer than Voyager at tropopause)

HD Abundance :

$HD/H_2 = 9 \pm 2 \times 10^{-5}$

Since $D/H = \frac{1}{2} HD/H_2$ → $D/H = 4.5 \pm 1 \times 10^{-5}$

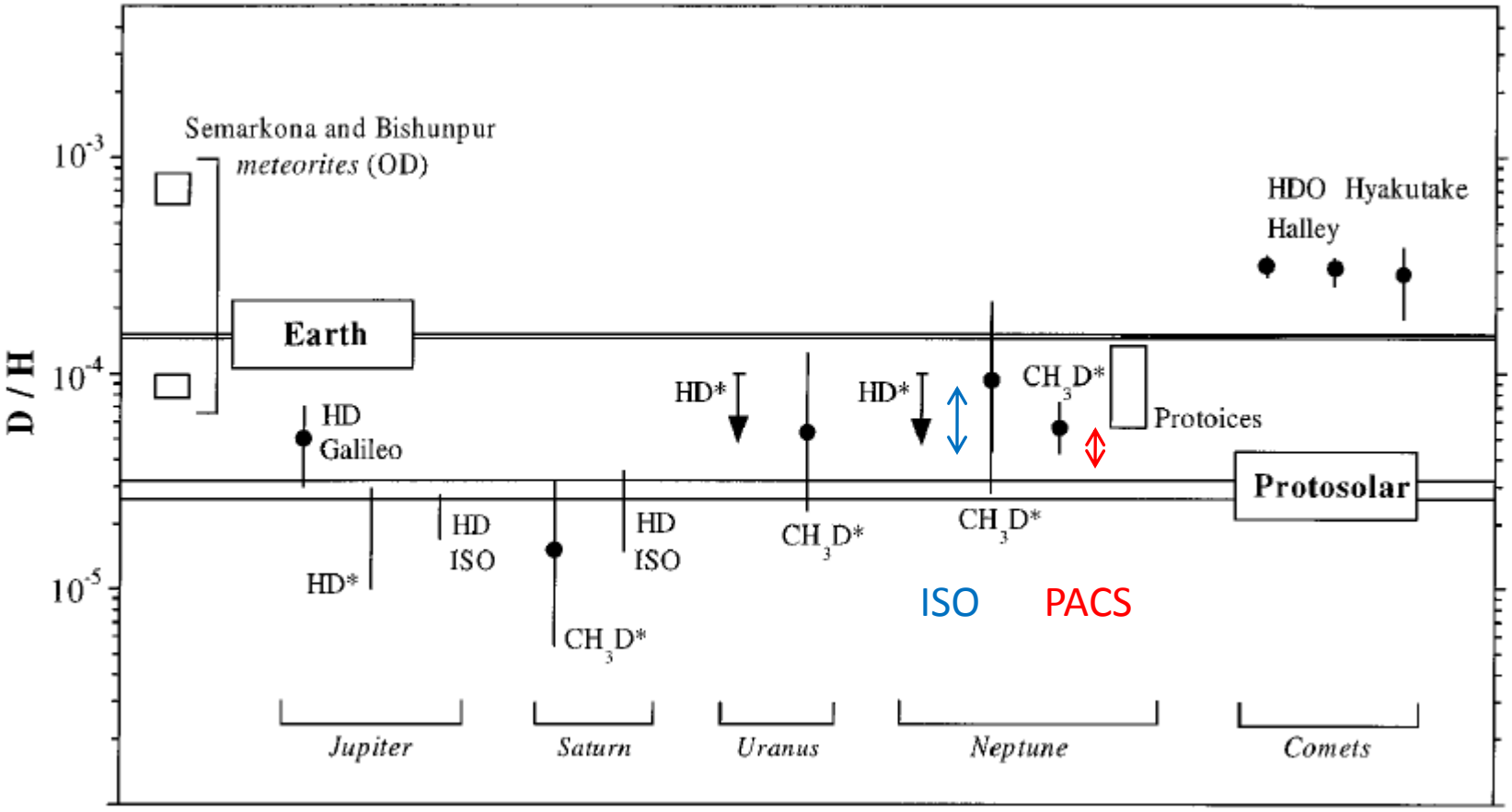
Nominally smaller but consistent with ISO Value

($D/H = 6.5 \pm 2 \times 10^{-5}$, Feuchtgruber *et al* 1999)

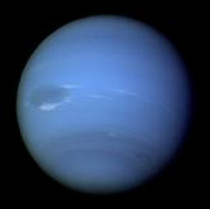
→ Confirms that Neptune is enriched in deuterium compared to the protosolar value ($D/H \sim 2.1 \times 10^{-5}$ on Jupiter and Saturn)

→ Implications on the composition of the icy grains that formed Neptune : $(D/H)ice \sim 7 \times 10^{-5}$ (~1/4 x Comet $D/H \sim 3 \times 10^{-4}$)

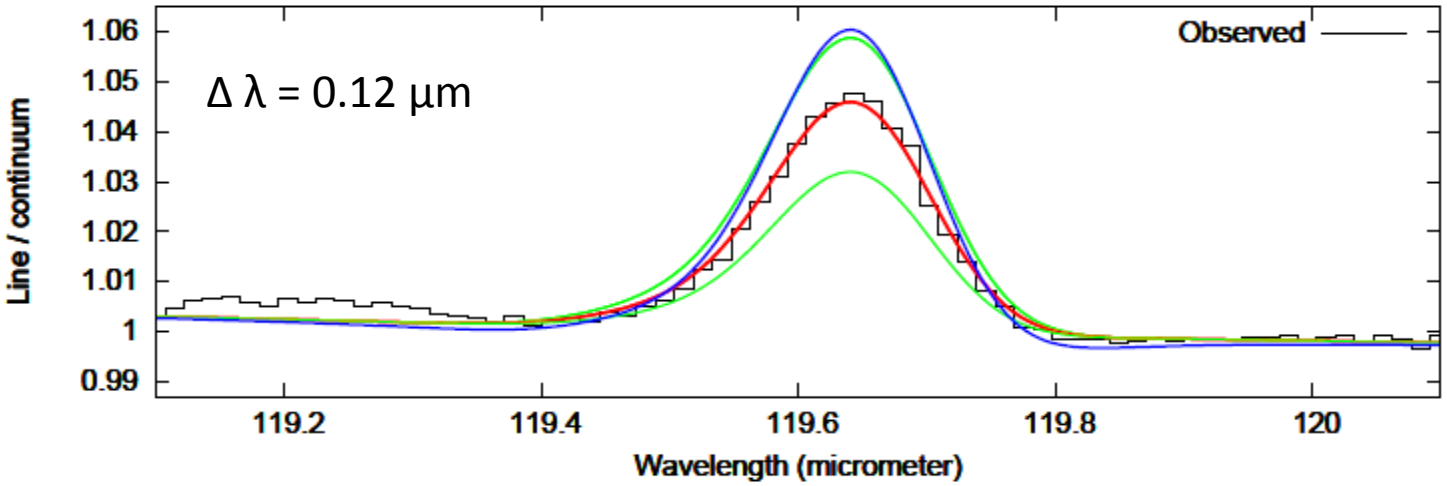
D/H over the Solar system

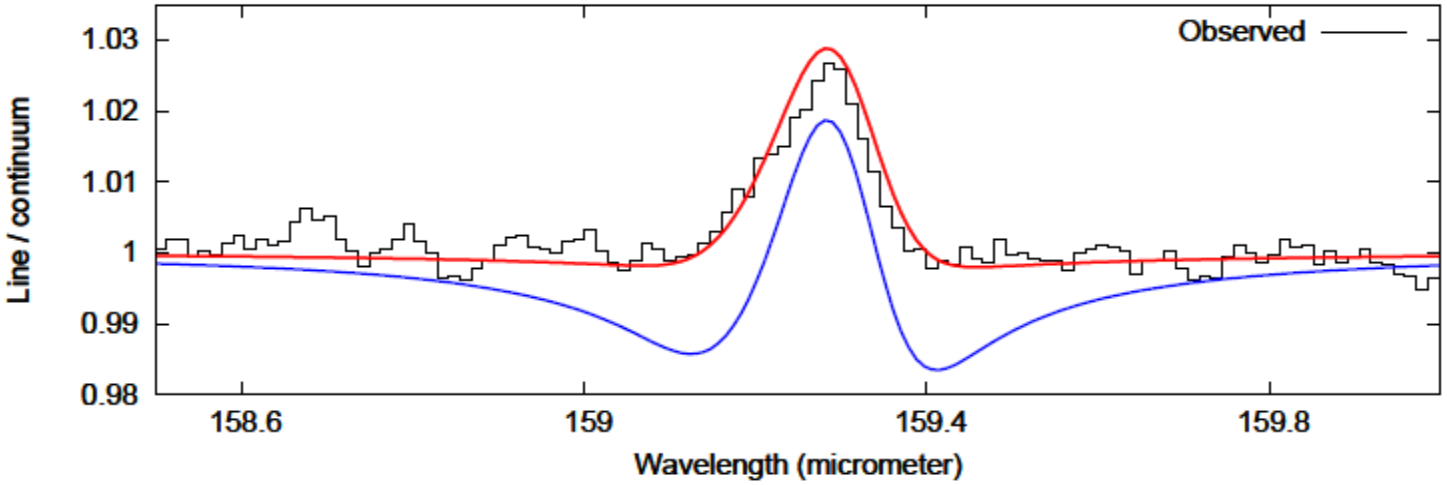


Bockelee-Morvan *et al* 1998



CH_4 - PACS

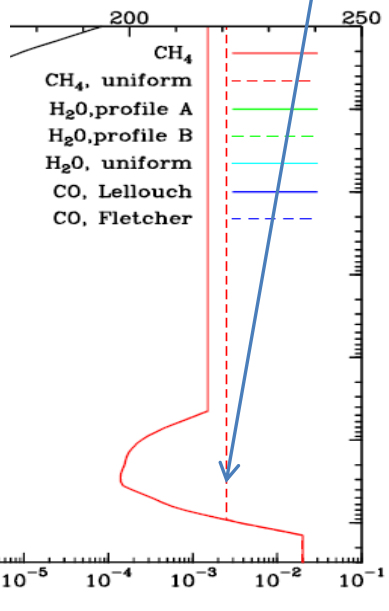


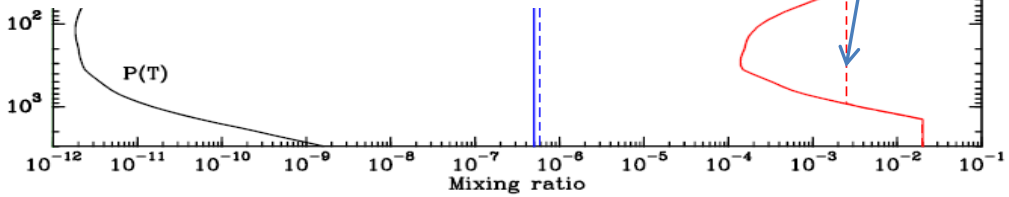


CH_4 (1.5×10^{-3})

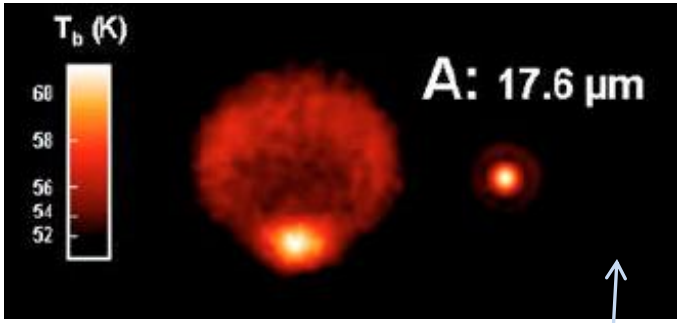
CH_4 ($1\text{-}2 \times 10^{-3}$)

CH_4 (2.5×10^{-3})
Down to 800 mbar





CH_4 - Results



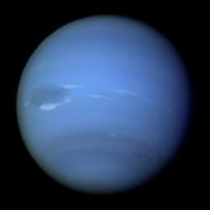
The retrieved stratospheric methane mixing ratio :

$$qCH_4 = 1.5 \pm 0.2 \times 10^{-3}$$

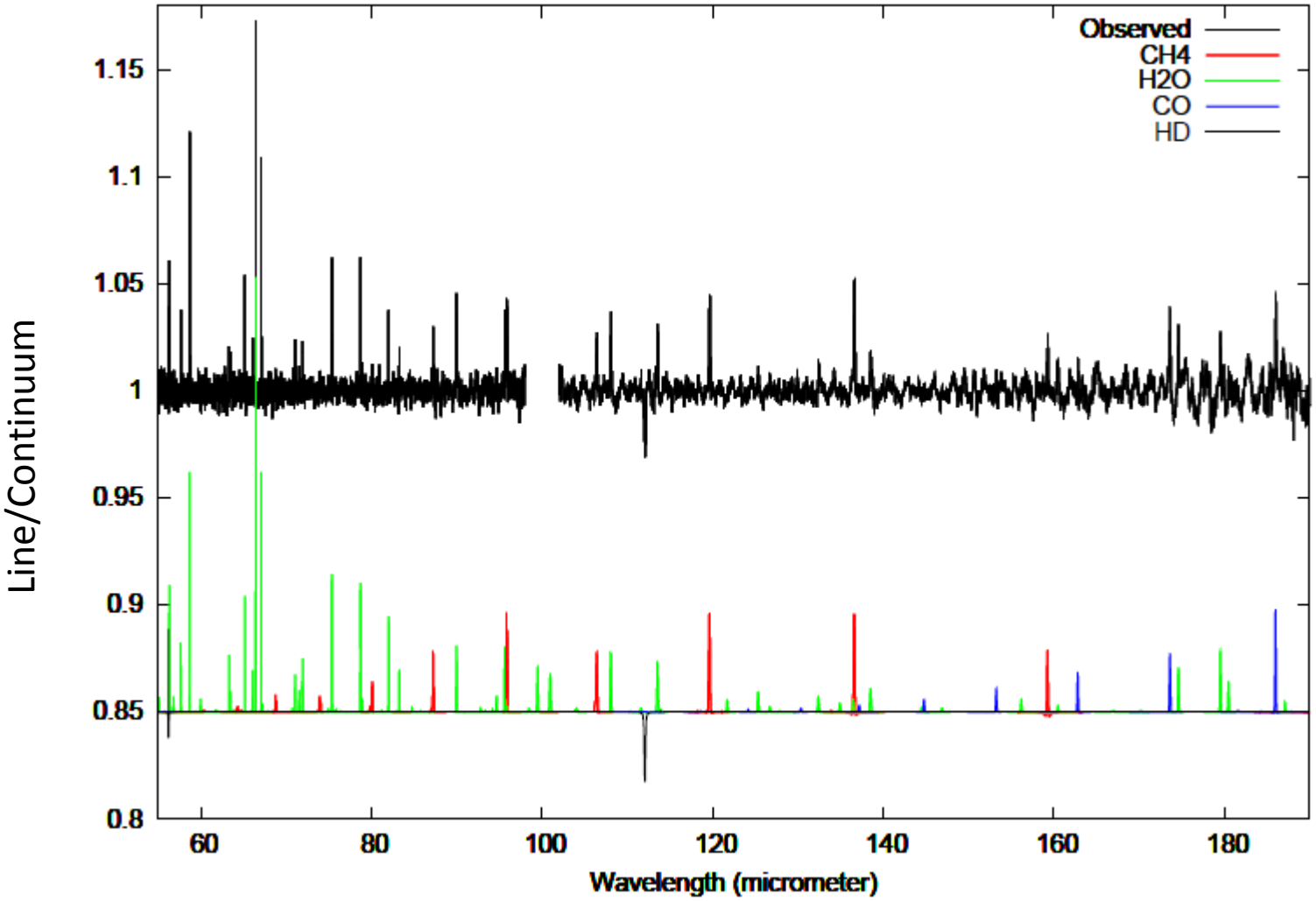
First precise measurement of CH_4 in Neptune's stratosphere

-smaller than the troposphere value (2%) , because of the condensation at the cold trap.
-nevertheless, exceeds the cold trap saturation value by factor 10

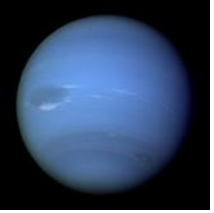
Most probable origin of this elevated value : CH_4 leaks from the warmer southern region (i.e. +6K from Orton et al 2007) and is redistributed planetwide by global circulation



H_2O – PACS

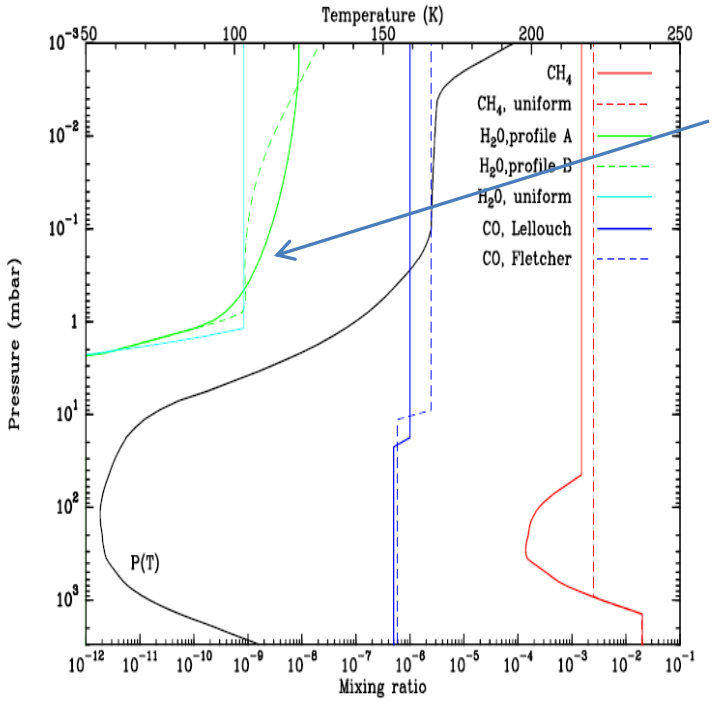


More than 20 lines of H_2O (unresolved)



H_2O - Results

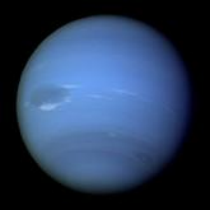
The presence of H_2O in giant planet stratospheres , including Neptune, was established by ISO, demonstrating the existence of an external oxygen supply, but the water vertical profile could not be determined.



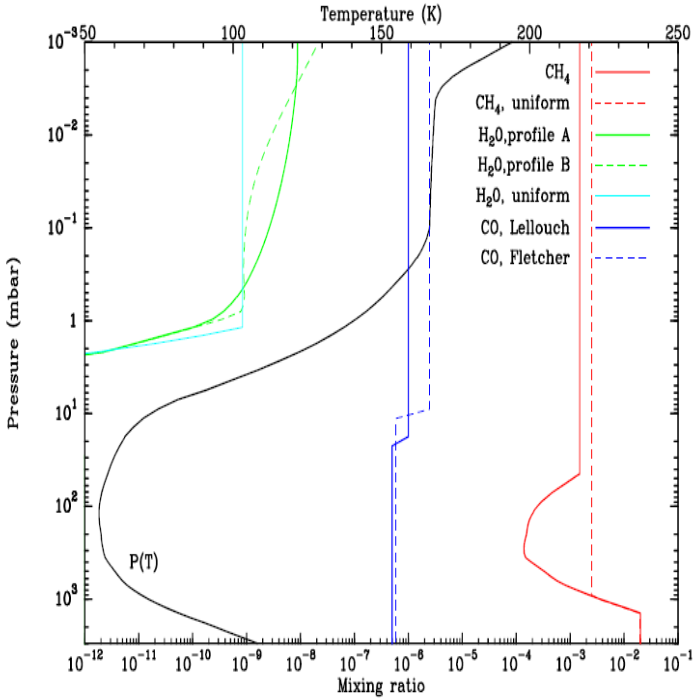
Current best fit of PACS spectrum suggests that H_2O increases with altitude from 1 to 0.1 mbar.

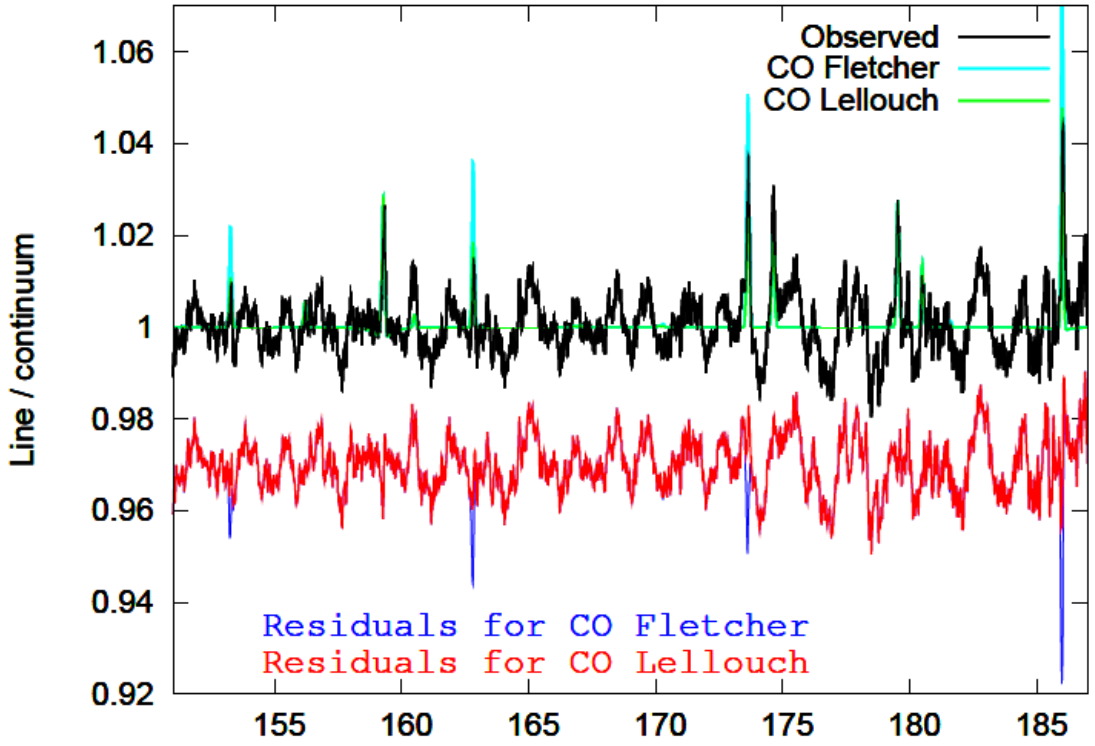
→Water external flux : 1.4x 10^{5} $cm^{-2}s^{-1}$

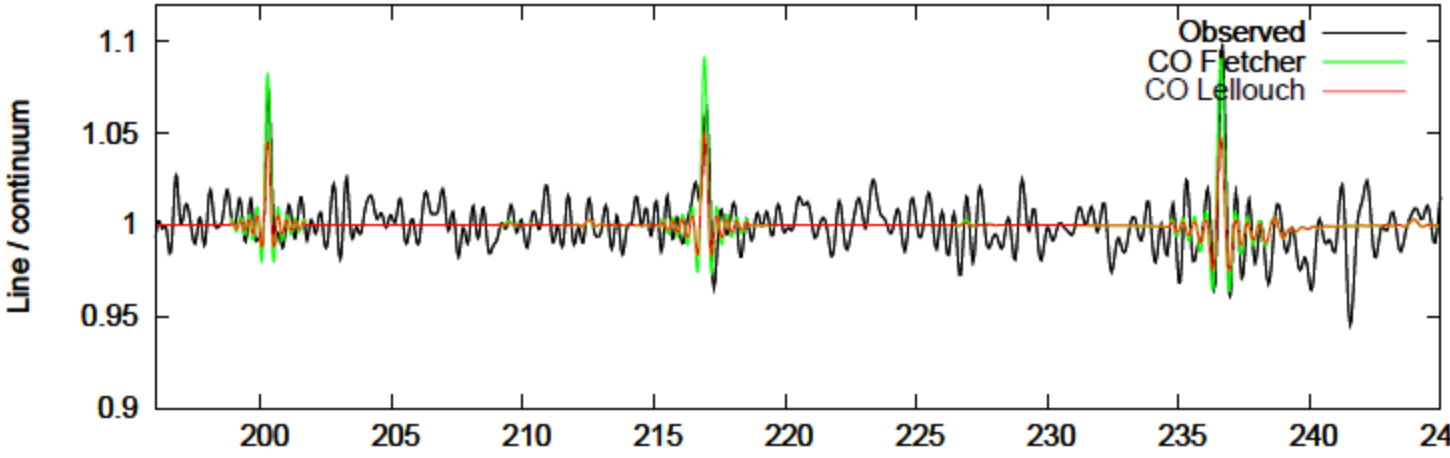
To be confirmed by higher SNR line observations (HIFI, PACS)

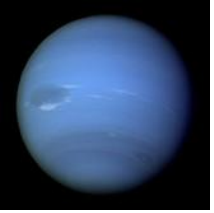


CO – PACS and SPIRE





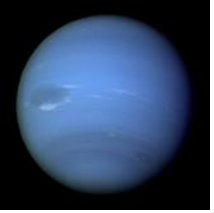




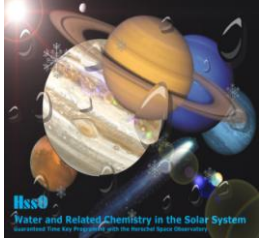
CO - Results

PACS and SPIRE confirm that CO abundance is higher by factor 2-4 in stratosphere than in troposphere.
→ This implies a dual external/internal source of CO , with the external source possibly provided by an ancient cometary impact.

Higher S/N SPIRE spectrum will be needed to improve CO profile



CONCLUSIONS



- High quality PACS spectrum, and preliminary SPIRE spectrum were obtained on Neptune.

- HD,CH_4,H_2O,CO well detected , but no new molecules.

- Additional observations to come :

-HIFI : H_2O at 557 GHz

-PACS : Dedicated H_2O line scans

-SPIRE : Higher S/N spectrum

- These observations + combined analysis with SPITZER and AKARI will allow to refine the P(T) and molecular abundances